

1     **PROCESS FOR SEQUENTIALLY APPLYING SAGD TO ADJACENT**  
2                     **SECTIONS OF A PETROLEUM RESERVOIR**

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4                     **FIELD OF THE INVENTION**

5             This invention relates to recovering heavy oil from an underground  
6     reservoir using a staged process involving, in the first stage, steam assisted  
7     gravity drainage, and in the second stage, non-condensable gas injection and  
8     reservoir pressurization.

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10                    **BACKGROUND OF THE INVENTION**

11            Steam assisted gravity drainage ("SAGD") is a process first proposed  
12     by R. M. Butler and later developed and tested at the Underground Test  
13     Facility ("UTF") of the Alberta Oil Sands Technology and Research Authority  
14     ("AOSTRA"). The SAGD process was originally developed for use in heavy  
15     oil or bitumen containing reservoirs, (hereinafter collectively referred to as  
16     'heavy oil reservoirs'), such as the Athabasca oil sands. The process, as  
17     practised at the UTF, involved:

- 18            • Drilling a pair of horizontal wells close to the base of the reservoir  
19              containing the heavy oil. One well was directly above the other in  
20              relatively close, co-extensive, spaced apart, parallel relationship.  
21              The wells were spaced apart 5 – 7 meters and extended in parallel  
22              horizontal relationship through several hundred meters of the oil  
23              pay or reservoir;

- 1       • Then establishing fluid communication between the wells so that  
2       fluid could move through the span of formation between them. This  
3       was done by circulating steam through each of the wells to produce  
4       a pair of "hot fingers". The span between the wells warmed by  
5       conduction until the contained oil was sufficiently heated so that it  
6       could be driven by steam pressure from one well to the other. The  
7       viscous oil in the span was replaced with steam and the wells were  
8       then ready for production;
- 9       • Then converting to SAGD production. More particularly, the upper  
10      well was used to inject steam and the lower well was used to  
11      produce a product mixture of heated oil and condensed water. The  
12      production well was operated under steam trap control. That is, the  
13      production well was throttled to maintain the production temperature  
14      below the saturated steam temperature corresponding to the  
15      production pressure. Otherwise stated, the fluids being produced at  
16      the production interval should be at undersaturated or "subcooled"  
17      condition. (Subcool = steam temperature corresponding to the  
18      measured producing production pressure – measured temperature.)  
19      This was done to ensure a column of liquid over the production well,  
20      to minimize "short-circuiting" by injected steam into the production  
21      well. The injected steam began to form an upwardly enlarging  
22      steam chamber in the reservoir. The chamber extended along the  
23      length of the horizontal portions of the well pair. Oil that had  
24      originally filled the chamber sand was heated, to mobilize it, and

1           drained, along with condensed water, down to the production well,  
2           through which they were removed. The chamber was thus filled  
3           with steam and was permeable to liquid flow. Newly injected steam  
4           moved through the chamber and supplied heat to its peripheral  
5           surface, thereby enlarging the chamber upwardly and outwardly as  
6           the oil was mobilized and drained together with the condensed  
7           water down to the production well.

8   This process is described in greater detail in Canadian patent 1,304,287  
9   (Edmunds, Haston and Cordell).

10          The process was shown to be commercially viable and is now being  
11   tested by several oil companies in a significant number of pilot projects.

12          Now, the operation of a single pair of wells practising SAGD has a finite  
13   life. When the upwardly enlarging steam chamber reaches the overlying, cold  
14   overburden, it can no longer expand upwardly and heat begins to be lost to  
15   the overburden. If two well pairs are being operated side by side, their  
16   laterally expanding chambers will eventually contact along their side edges  
17   and further oil-producing lateral expansion comes to a halt as well. As a  
18   result, oil production rate begins to drop off. As a consequence of these two  
19   occurrences, the steam/oil ratio ("SOR") begins to rise and continued SAGD  
20   operation with the pair eventually becomes uneconomic.

21          If one considers two side-by-side SAGD well pairs which have been  
22   produced to "maturity", as just described, it will be found that a ridge of  
23   unheated oil is left between the well pairs. It is of course desirable to  
24   minimize this loss of unrecovered oil.

1 In Canadian patent 2,015,460 (Kisman), assigned to the present  
2 assignee, there is described a technique for limiting the escape of steam into  
3 a thief zone. For example, if steam is being injected into a relatively  
4 undepleted reservoir section and there is a nearby more depleted reservoir  
5 section, forming a low pressure sink, there is a likelihood that pressurized  
6 steam will migrate from the undepleted section into the more depleted section  
7 – which is an undesired result. One wants to confine the steam to the  
8 relatively undepleted section where there is lots of oil to be heated, mobilized  
9 and produced. The Kisman patent teaches injecting a non-condensable gas,  
10 such as natural gas, into the more depleted section to raise its pressure and  
11 equalize it with the pressure in the relatively undepleted section. By this  
12 means, the loss of steam from the one section to the other can be curtailed or  
13 minimized.

14           The Kisman patent further teaches that pressurizing the more depleted  
15    section with natural gas has been characterized by an increase in production  
16    rate from that section, if the production well penetrating the section is  
17    produced during pressurization.

18 **SUMMARY OF THE INVENTION**

19 In accordance with the present invention, a novel process is provided  
20 for producing adjacent sections of an underground reservoir containing heavy  
21 oil. Each section is penetrated by one or more wells completed for SAGD  
22 operation, preferably one or more pairs of horizontal injection and production  
23 wells. The process comprises:

- 1 (a) injecting steam into the first section of the reservoir to practice  
2 SAGD and produce contained oil, until the steam/oil ratio rises  
3 sufficiently so that further production by SAGD from the section  
4 is substantially uneconomic;
- 5 (b) then reducing or terminating steam injection into the first section  
6 and injecting non-condensable gas into the section to maintain it  
7 pressurized;
- 8 (c) continuing to produce oil from the first section while it is  
9 pressurized; and
- 10 (d) concurrently with step (c), injecting steam into the adjacent  
11 second section to practice SAGD therein and produce contained  
12 oil;
- 13 (e) while preferably maintaining the first section pressurized to  
14 substantially the same pressure as exists in the second section  
15 during step (d).
- 16 Steps (b) and (c) constitute a post-steam wind-down of oil production  
17 from the first section. Over time, oil production rate will drop off during wind-  
18 down and eventually it will again become uneconomic to justify continuing to  
19 produce the first section. However it may still be desirable to continue  
20 maintaining pressurization in the first section to limit steam loss from the  
21 second section.

1       The process provides a strategy for sequentially producing adjacent  
2 sections across the reservoir. It takes advantage of gas pressurization to  
3 prevent steam leakage from a less depleted section undergoing SAGD to a  
4 mature, more depleted section. It also maximizes production from each  
5 section by subjecting it to sequential SAGD and pressurization production  
6 stages.

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8                   **DESCRIPTION OF THE PREFERRED EMBODIMENT**

9       In accordance with the best mode of the process known to the  
10 applicants, it comprises:

- 11       (a)   directionally drilling one or more pairs of wells from ground  
12             surface into a reservoir first section, to provide generally parallel,  
13             horizontal, co-extensive, spaced apart, upper and lower well  
14             portions extending through the section, and completing the wells  
15             for SAGD production;
- 16       (b)   establishing fluid communication between the injection and  
17             production wells of each pair, for example by circulating steam  
18             through both wells, to heat the span between the wells by heat  
19             conduction, and then displacing and draining the oil in the span  
20             by injecting steam through the upper injection well and opening  
21             the lower production well for production;

1 (c) practising SAGD in the reservoir first section by injecting steam  
2 through the injection wells and producing the produced heated  
3 oil and condensed water through the production wells while  
4 operating said production wells under steam trap control;

5 (d) preparing a second adjoining section of the reservoir for SAGD  
6 production by carrying out the provision of wells and establishing  
7 fluid communication between the wells of each pair as in steps  
8 (a) and (b);

9 (e) terminating or reducing steam injection into the reservoir first  
10 section injection wells and initiating natural gas injection through  
11 said injection wells to increase the pressure in the reservoir first  
12 section to about the anticipated steam injection pressure in the  
13 reservoir second section and maintaining the pressure at about  
14 this level while simultaneously producing residual heated oil and  
15 steam condensate through the production wells under steam  
16 trap control; and

17 (f) concurrently with step (e), practising SAGD in the reservoir  
18 second section.

19 In connection with practising steam trap control with wells extending  
20 down from ground surface and having riser and horizontal production  
21 sections, it is preferred to operate as follows:

- 22 • measuring the downhole temperature at the injection and  
23 production wells of an operating pair, using thermocouples;

- 1           • establishing the temperature differential between the two wells and
- 2           throttling the production well to maintain the differential at a
- 3           generally constant value (say 7°);
- 4           • monitoring for significant surges in vapour production rate at the
- 5           ground surface production separator and for surges in steam
- 6           injection rate; and
- 7           • adjusting throttling to minimize the surges.

8   Otherwise stated, a generally constant liquid rate at the wellhead is  
9   maintained and the bottomhole production temperature is allowed to vary  
10   within a limited range.

11       The invention is characterized by the following advantages:

- 12       • additional oil is recovered from the mature wells during the gas
- 13       pressurization stage, while simultaneously reducing steam leakage
- 14       from the second reservoir section;
- 15       • use is made of the residual heat left in the mature reservoir section;
- 16       and
- 17       • a finite steam-producing plant can be applied in sequence to a
- 18       plurality of adjacent sections of the reservoir, without severe steam
- 19       loss from a section undergoing SAGD to an adjacent depleted
- 20       section.